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November 24, 1993

By Hand

Mr. William F. Caton
Acting Secretary
Federal Communications Commission
1919 M Street, NW
Washington, DC 20554

Re: Ex Parte Presentation
CC Docket No. 92-297

Dear Mr. Caton:

On behalf of Suite 12 Group ("Suite 12"), petitioner in the above-referenced rulemaking proceeding, enclosed please find two (2) copies of a technical study prepared by engineer-inventor Bernard B. Bossard demonstrating that the Local Multipoint Distribution Service ("LMDS") does not interfere with the NASA ACTS satellite system ("ACTS"), and that LMDS is sound and economically viable.

In its Comments filed in the above-referenced proceeding, NASA stated that an appropriate interference to noise ratio, Io/No, at its ACTS satellite receiver would be about -10 dB. See Comments of NASA, March 16, 1993, at Appendix B, page 14. NASA's own calculations regarding potential interference to ACTS from LMDS yielded a Io/No ranging from -1.7 to -12.5 dB. Id.

The enclosed study, however, demonstrates that in calculating the potential interference to ACTS from LMDS, NASA made numerous significant errors and improper assumptions which produced severely overstated interference estimates. Accordingly, when these NASA errors are identified and corrected, and the proper calculations are made, the potential interference to ACTS CONUS 32 dB antenna from LMDS actually is -37.9 dB, and possibly as low as -39.9 dB. In addition, the properly calculated potential interference to ACTS 53 dB antenna, for a representative sampling of major cities, ranges from -30.4 dB to -39.6 dB. Importantly, not only are these interference calculations well within NASA's own acceptable parameter of -10 dB,

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these calculations demonstrate that any potential interference to ACTS from LMDS is virtually unmeasurable.

The study also responds to several inaccurate assertions about LMDS made by NASA in order to reiterate both the technical and economic viability of LMDS.

Please place these two copies of this technical study in the above-referenced docket. Any questions regarding this study should be directed to the undersigned.

Sincerely,

Michael R. Gardner
Charles R. Milkis
Counsel for Suite 12 Group

Enclosures

cc Thomas Tycz, Deputy Chief, Domestic Facilities Division
Robert James, Chief, Domestic Radio Branch
Harry Ng, Senior Engineer, Satellite Radio Branch
Susan E. Magnotti, Esq.

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LMDS Does Not Interfere with NASA ACTS

LMDS is Both Practical and Economically Viable

by
Bernard B. Bossard

SUMMARY

This paper addresses the questions raised by NASA regarding the potential interference with the NASA ACTS geosynchronous satellite as well as questions about the viability of the LMDS approach itself.

Specifically, it is shown that the calculations made in the NASA filings in the LMDS proceeding do not, when applied to the physical parameters of the ACTS and LMDS systems, yield nearly as much potential radio interference as was claimed by NASA; and, in fact, the likely interference level is actually a factor of more than 100 below that which NASA itself defines to be acceptable. Such a low potential interference would be virtually unmeasureable.

It is shown that the substantial differences in interference levels calculated by NASA and those used in the LMDS design arise because of incorrect and/or inconsistent application of data and assumptions employed by NASA.

Concerning the viability of the LMDS approach, it also is shown that, contrary to the opinions expressed by NASA:

- cell head ends are economically realizable as a result of polarization isolation which allows for reuse of the spectrum in adjacent cells, and also for point to point repeater interconnects;
- antenna sites are available, even in crowded New York City, through locators, and they are economical due to the low profile of the LMDS equipment;
- LMDS antenna polarization diversity is effective, as demonstrated by measurements;
- fade margins of the system have been verified as adequate by independently conducted measurements; and
- rain does not have as high an attenuation effect on LMDS signals as NASA suggests, because of the fact that signals are not propagated across cell diameters as NASA assumed but rather from cell center to perimeter, as well as the fact that the LMDS design takes into account rainfall data for each cell location in determining cell radius.

INTRODUCTION

This paper is in response to the various submissions of NASA in the Local Multipoint Distribution Service ("LMDS") rulemaking proceeding and, in particular, the NASA submission entitled "Comments of the National Aeronautics and Space Administration" (Reference 1), hereinafter called the "NASA Document", regarding the design and operation of the LMDS. The NASA Document purports that the potential radio interference by LMDS with the NASA ACTS satellite receiver is excessive. In this paper it is shown that when the proper physical data and assumptions are applied to the calculations of potential interference to the NASA ACTS satellite communication system by LMDS, the potential interference levels are a relative factor of more than 100 below those estimated by NASA, and that on an absolute basis they are actually well below the 10 dB signal to interference level recommended as acceptable by NASA itself within the NASA Document.

In addition, in the NASA Document issues are raised by which it is suggested that the LMDS is not practical or economically viable. These issues, too, are addressed in this paper, showing that when the proper radio design calculations are applied to the LMDS the resulting system is both physically efficacious as well as economically viable.

Technical Discussion

From the NASA Document, Table 4.3.1-1 is repeated below for the reader's convenience.

Table I. (Figure 4.3.1-1, from the NASA Document) Maximum interference to GEO satellite uplinks from LMDS transmitters

System	Type	Coverage Area in Sq. Mi.	Maximum # LMDS	Aggregate Interfer. (dBW/Hz)	Thermal Noise (dBW/Hz)	Io/No (dB)
ACTS	GEO	121,875	6,094	-200.7	-199.0	-1.7
ACTS	GEO	1,146,241	57,312	-200.9	-199.0	-2.0
ACTS	GEO	1,760,078	88,004	-201.1	-196.6	-4.5
ACTS-LIKE	GEO	3,500,000	175,000	-212.1	-199.6	-12.5
NORSTAR	Feed to GEO	3,500,000	175,000	-200.1	-195.6	-12.5
NORSTAR	User to GEO	2,216,000	110,000	-201.1	-195.6	-5.5

From this Table it can be seen that the NASA calculated interference to noise ratio, Io/No, at the input of its geostationary satellite receiver varies from -1.7 to -12.5 dB depending on the gain of the NASA antenna employed. The NASA Document states on page B-14 and page 21 that an "appropriate criteria would appear to be an Io/No of about -10 dB". Thus it is NASA's recommendation that the interference from LMDS should not exceed 1/10th the noise level of its satellite receiver.

NASA does not include the methods of calculation it used to generate this data. However, within the NASA Document the following basic information is stated:

(1) The ACTS GEO Satellite receiver ("spot") antenna gain is 53 dB (page B-13, table 4.3.1)

(2) The other satellite receiver antenna gain for Conus (whole continental United States) Coverage is 32 dB (page B-13)

(3) The arrival angle from earth to the geosynchronous satellite is a minimum 30° (with respect to the zenith), (page B-13)

(4) The geostationary orbit of the satellite (page B-13) distance is 24,009 miles (paragraph 4.2, Freeman Report, April 11, 1993, Reference 2).

In this paper, we base our correcting calculations on the assumption that items (1) through (4) above are correct. In the NASA Document several of the physical assumptions and approximations are found to be improper and/or inconsistent. The result is that the important interfering signal to noise (Io/No) ratio calculations by NASA are grossly in error, in some cases by a factor of more than 100. Accordingly, NASA's conclusions about the ability of the two systems, the NASA ACTS and the LMDS, to operate without interference are incorrect. That is, while NASA concludes that there would be too much interference, in fact, when the radio calculations are applied in a thorough manner, it is found that there is so little interference (less than 1/100 of the ambient noise level) that it would be virtually unmeasureable.

Specifically, the nature of the errors in the NASA calculations will be discussed in the following categories:

A) LMDS antenna gain in direction of satellite
B) NASA Satellite receiver antenna coverage area on earth
C) LMDS cell area
D) Variation of satellite antenna gain over coverage area
E) Assumption that all LMDS transmitters have the same polarization
F) Assumption of uniform distribution of LMDS cells
G) Atmospheric losses

We now consider each of the above points as they are treated in the NASA Document and how errors in these treatments influence the summary Io/No ratio. The summation of these NASA errors, expressed in decibels (dB) represents the total error, which, as will be shown well exceeds -20 dB, for an error ratio of over 100 to 1.

This error on NASA's part is unduly pessimistic regarding the ability of the two systems to coexist, and leads NASA to the erroneous conclusion that such simultaneous use of the spectrum by both systems is impractical. In fact, application of standard radio system considerations demonstrates that both systems can co-exist.

ERRORS FOR THE ACTS CONUS (32 dB) ANTENNA

We begin the interference evaluation for the case of the ACTS Conus (Continental United States) area coverage antenna. This satellite receiver antenna has a gain of 32 dB. Errors in the NASA Document are evaluated as error ratios for the points A) through F) listed in the INTRODUCTION.

A) **LMDS antenna gain in the direction of the satellite**: NASA assumed the LMDS omni directional transmitter antenna has a 0 dB gain in the direction of the their satellite receiver with a worst case 30° elevation angle (Reference 1, page B-13). Figure A indicates a typical LMDS omni-directional transmitting antenna pattern. In this Figure angles are measured clockwise from the horizontal. Thus, for example, the antenna is pointed skyward (zenith) at an angle of -90°. At the +30° elevation angle (switching to the more easily visualized degrees elevation above the horizon), there is a 25 dB rejection for the LMDS 10 dB gain antenna and a 27 dB rejection for the LMDS 14 dB gain antenna. Thus, the actual LMDS antenna gain at the 30° angle is either -15 dB or -13 dB, not 0 dB as calculated within the NASA Document. This results in a minimum NASA error of -13 dB.

Moreover, the ACTS design parameters indicate that major cities do not have as low a pointing angle as 30°, but rather they are directed even more skyward, further increasing their isolation to terrestrial signals on the horizon such as those of the LMDS. For example, the following elevation angles (ACTS System Antenna Coverage, Appendix 1) apply to selected major cities:

Table II. Angles above the horizon at which the ACTS Geosynchronous satellite must be viewed from various major U.S. cities.

New York	35.9°
Seattle	31.2°
Los Angeles	45.8°
Miami	52.6°

The effect of these higher siting angles makes the isolation afforded by the directivity of the LMDS antenna even greater, to isolation values as high as -30 dB. In our summary, we will take a conservative approach and consider the error as being between -13 to -15 dB. However, the actual NASA error for virtually every American city will be higher than this -13 to -15 dB range.

B) **NASA Satellite Receiver Antenna Coverage Area on Earth**: The NASA Document utilizes an earth coverage area of 3,500,000 square miles for the 32 dB gain satellite antenna. The actual coverage is 3,000,000 square miles (Appendix 3). The error ratio is 3,500,000/3,000,000 = 1.17. Expressed in decibels, the NASA error is -0.7 dB.

This error in the NASA Document has the effect of assuming that there are too many LMDS transmitters in the beam of the satellite antenna and, accordingly, it contributes to NASA's erroneously high interference signal level.

C) **<u>LMDS Cell Area</u>**: NASA assumed the maximum LMDS cell area to be 20 square miles and used that "smallest cell size, maximum density" for the calculation of the total number of LMDS cells throughout the United States (page B-13, Reference 1). This assumption was made by NASA in spite of the fact that, elsewhere, it acknowledged that the New York cell diameter is 7.8 miles, for an area of 48 square miles, and the Los Angeles cell diameter is 12.4 miles, for an area of 121 square miles (Figure 2-1, page B5, Reference 1). The effect of this computational inaccuracy in the NASA Document also serves to increase the number of LMDS transmitters in a given satellite antenna terrestrial footprint, and with it the amount of interference to be estimated.

In fact, the actual cell diameters in the LMDS system are determined by the anticipated amount and frequency of rainfall in the cell's area. This is because the available transmitter power is fixed and the radius of propagation for the LMDS signal is set by the rain attenuation to be anticipated and the fact that the system is designed to have an availability of 99.9% with a fringe area baseline video signal to noise ratio (S/N) of 54 dB.

Figure C indicates the geographic regions of similarity in rainfall statistics and the following table translates the expected rainfall attenuation for that region in dB per mile. Note that New York City is part of region D-2, in which expected rainfall is more intense. It has a rain attenuation allowance of 4.6 dB per mile in the LMDS design, resulting in an atypically small cell size. The rainfall allowance for various regions in the United States and their accompanying signal attenuation allowances made in the LMDS design are shown in Table III below.

Table III. Expected rainfall in various areas of the United States (see Figure C) and the corresponding LMDS cell areas (based on rainfall attenuation of the signals).

Region	mm/hr	Attenuation/mile	Area sq.mi.
F	5.5	1.5 dB	109
B	6.8	1.8 dB	92
C	7.2	2.0 dB	82
D1	11	3.2 dB	48
D2	15	4.6 dB	30
D3	22	6.7 dB	20
E	35	11.00 dB	9

To be conservative, we used 5.0 dB for the New York area (Region D2) in our rulemaking calculations (page 22 of Petition for Rulemaking, Appendix B, Reference 3). Note that the cell size areas in the United States range up to 109 square miles. In making calculations related to the Conus antenna, which covers most of the United States, we use a geometric weighting of the cell sizes in order to best describe how many LMDS transmitters will be employed. With this approach, the average LMDS cell size for 100% United States coverage at 99.9% availability is estimated to be 52 square miles, and not the 20 square miles NASA assumed. The effect of this correction to the error in the NASA Document calculations is a factor of 52/20 = 2.6. Expressed in decibels, this is a -4.1 dB error.

The miscalculations in (B above), earth coverage area and (C above), LMDS cell size, will result in substantially less LMDS transmitters within the NASA ACTS Satellite's antenna footprint and accordingly less actual interference than estimated in the NASA Document.

Hence, while NASA concludes that the LMDS must have 175,000 cells (3,500,000/ 20), or 175,000 transmitters, the actual number using the same reasoning would be only 57,693 transmitters (3,000,000 square miles/52 square miles). Even this reduced number, less than one third of the quantity of transmitters estimated by NASA, is more than will likely be needed to furnish service to 90% of the population in the United States. Population density is not uniform over the Country, with more than 90% of the population living in less than 40% of the land area. This produces a further correction, which is calculated later (in section F).

D) **Variation of Satellite Antenna Gain Over Coverage Area**: The NASA Document calculations are further pessimistic because there is less gain of the satellite antenna at the edges of coverage. If the antenna has a 3 dB beamwidth over the coverage area, then the signal sensitivity is reduced by 3 dB at the band edges and, on average by 1.5 dB over the coverage area. In this section, calculating the NASA error with regard to Conus antenna coverage, we neglect this factor; however it is taken into account in the spot beam calculations later.

E) **Assumption that all LMDS Transmitters Have the Same Polarization**: NASA incorrectly assumed that all LMDS emitters have the same polarization as the NASA Satellite receiver. Clearly the NASA receiver has a fixed polarization that does not change within its sector of coverage. By contrast the LMDS system alternates between vertical and horizontal polarizations from cell to cell. Accordingly, no matter what polarization the satellite receiver employs (circular polarization, right or left, or linear polarization, vertical or horizontal), the satellite receiver will be, on average, receptive to only one half of all of the signal energy of all of the nationwide distribution of LMDS transmitters. This represents an error in the NASA Document of 50%, or -3 dB.

F) **Assumption of Uniform Distribution of LMDS Cells**: The calculations made in the NASA Document assume that LMDS cells would be distributed uniformly throughout the United States. However, this assumption by NASA overlooks the fact that the population of system subscribers are not so uniformly distributed. Clearly, there is a great difference in the population densities between, for example, New York City, and the large land areas in the Southwest. For conservative planning purposes, a worst-case assumption is that 90% of the population live in 40% of the land area in the country. For example, in the New York MTA, 90% of the population lives in 33% of the area. Accordingly, since most of the country's population is concentrated in less than half of the country's land area, LMDS transmitters will probably occupy only about 40% of the country's total land area. Thus, using an average cell area of 52 square miles, for the 3,000,000 square mile area of the United States (Reference 6), the LMDS area covered would be 1,200,000 square miles. This would require 23,078 LMDS transmitters (using an average cell size of 52 square miles, 1,2000,000/52 = 23,078), which is in sharp contrast to the NASA Document estimate of 175,000 cells. Since the area coverage of LMDS cells was treated separately in earlier sections, we add only the 40% land area correction here. This is a factor of 1.00/0.40 or 2.5. Expressed in decibels, this is a -4.0 dB error.

G) **Atmospheric Losses**: Attenuation in the atomosphere introduces only a factor of -0.6 dB.

Summarizing, the results of A) through G) above, the total miscalculation factor in the NASA Document is as shown in Table IV below.

Table IV. Summary of the NASA error factors as they pertain to LMDS potential interference into the ACTS 32 dB antenna.

		Error Min	Error Max or Probable
A) LMDS Antenna Gain		-13.0 dB	-15.0 dB
B) ACTS Terrestrial Footprint		-0.7 dB	-0.7 dB
C) LMDS Cell Area		-4.1 dB	-4.1 dB
D) ACTS Antenna Gain at Edges		---	---
E) Polarization		-3.0 dB	-3.0 dB
F) Non-uniform LMDS cells		-4.0 dB	-4.0 dB
G) Atmospheric Losses		-0.6 dB	-0.6 dB
	Total	-25.4 dB	-27.4 dB
NASA calculation before correction:	Io/No =	-12.5 dB	-12.5 dB
Corrected NASA calculation	Io/No =	-37.9 dB	-39.9 dB

From this summary, the error introduced into the calculations in the NASA Document through misapplication of the relevant technical values and assumptions appropriate for radio systems is at least a factor of 25.4 dB too high and, possibly, as much as 27.4 dB too high. This means that the estimate of noise introduced into the satellite receiver is overstated by NASA by at least a factor of nearly 350 and, possibly, over 500!

Not only is the relative noise calculation in the NASA Document high by a large factor, the absolute amount of the noise introduced into the receiver is at least 37.9 dB below the ambient noise and, possibly, 39.9 dB. This is at least a full

27.9 dB below that figure which NASA itself recommended as satisfactory in the NASA Document and, possibly, as much as much as 29.9 dB, a factor of nearly 1000 better than NASA predicts. Most importantly, this means that the interfering signal at the satellite's Conus antenna is less than 1/6000th of the background noise! This would be indescernible by any measurement.

ERRORS WITH THE 53 dB ACTS ANTENNA

The factors of error in the NASA Document calculations as they apply to the high gain "spot" satellite antenna are estimated in a similar fashion. However, in this case there is a much larger error apparent in the NASA calculation for the terrestrial coverage area, or "footprint." A proper radio interference calculation in this case must take into account three important variables. These are 1) the LMDS antenna gain in the direction of the satellite, 2) the footprint in square miles of the satellite antenna, and 3) the LMDS cell density in the satellite antenna footprint.

In order to perform these calculations in a manner which neither overstates nor understates the potential interference, we will consider four separate cities in the United States, which are representative of the different cell diameters (related to rainfall) and angles of elevation relative to the geosynchronous satellite. The calculations are performed in a fashion similar to that used for the Conus antenna. It is our understanding, based on our review of NASA filings and conversations with NASA officials, that the 53 dB spot beam antenna covers only one area at a given time.

A) **LMDS antenna gain in direction of satellite**: As noted previously, the NASA calculations treated the LMDS transmitting antenna as having 0 dB gain in the direction of the satellite. For four typical U.S. cities the elevation angles to the satellite are carried forward from Table II to Table V below. Also shown is the net gain of the 10 dB and 14 dB LMDS transmitting antennas at these elevations.

Table V. Elevation angles to the ACTS satellite from major cities and the net antenna gain of the LMDS 10 dB and 14 dB transmitting antennas at those elevation angles.

	New York	Seattle	Los Angeles	Miami
Elevation Angle (deg)	35.9	31.2	45.8	52.6
LMDS Sidelobe 10/14 dB gain Antennas (dB)	-25/-30	-23/-25	-27/-30	-30/-30
LMDS Net Gain at Elevation Angle (dB)	-15/-16	-13/-11	-17/-16	-20/-16
NASA assumed Net Gain (dB)	0	0	0	0
NASA error (dB)	-15/-16	-13/-11	-17/-16	-20/-16

The error in NASA's interference estimate arises because NASA's calculation does not take into account that, particularly in cities with a high elevation angle toward the satellite, the terrestrial based LMDS antenna is looking essentially horizontally and the satellite has a high angle in the sky at which the LMDS antenna sidelobe is low. Consequently, the LMDS antenna radiates much less energy toward the satellite than estimated by NASA using the NASA 0 dB net gain assumption. From the Table it can be seen that this introduces a minimum error of -13 dB, and an error as great as -20 dB, an error factor in the NASA calculation of as much as 100.

B) **NASA Satellite receiver antenna coverage area on earth**: In the NASA Document an earth coverage area of 121,875 square miles for the 53 dB gain satellite antenna (Figure 4.3.1-1, page B-14) was assumed by NASA. This is in error and may represent the inadvertent interchange of some other antenna pattern with the spot beam coverages. However the error occurred, it is substantial.

Consider that a 53 dB gain antenna, of necessity, has a beam width of only 0.32°. (see Appendix 2 for calculation). It should be noted that the NASA Document, itself, indicates a 0.33° beam width, confirming our estimate, and a coverage diameter of 135 miles (page 2, Appendix 1). But this coverage diameter, derived from simple trigonometry, applies for a near 90° elevation angle (tan 0.33° x 24,009 miles = 135 miles). Using this 135 mile diameter results in an area of only 14,314 square mile coverage, not 121,875 square miles as NASA claimed. However, a somewhat larger footprint results because the satellite is in a geosynchronous orbit (in the Equatorial plane) and cities view it at an elevation angle which varies according to their locations, as was shown in the previous section in Table V.

It turns out that the footprint of the satellite antenna is proportional to the cosecant of the elevation angle. Thus, for example, for an elevation angle of 30°, the footprint for a 53 dB gain antenna on earth is 28,415 square miles (see Appendix 2 for calculations), still much less than the NASA 121,875 square mile value. Using the formulas presented in Appendix 2 or the cosecant approximation, the footprint values of the antenna at the elevations of the four representative cities are shown below in Table VI.

Table VI. Footprints of the ACTS 53 dB gain antenna at the elevations of representative U.S. cities and the corresponding NASA interference calculation error factors.

	New York	Seattle	Los Angeles	Miami
Elevation Angle (deg)	35.9	31.2	45.8	52.6
NASA 53 dB gain antenna actual foot-print (sq. miles)	19,930	27,596	17,610	13,147
NASA assumed footprint (sq. miles)	121,875	121,875	121,875	121,875
NASA error (dB)	-7.8	-6.5	-8.4	-9.7

This error in the NASA Document has the effect of assuming that there are too many LMDS transmitters in the beam of the satellite antenna and, accordingly, it calculates an improperly high interference signal level. The lowest error ratio is 121,875/ 27,596 = 4.42. Expressed in decibels, this is an error of -6.5 dB. The error is greater for other cities, up to -9.7 dB.

C) **LMDS cell area**: Continuing in the analysis in the manner used for the Conus antenna calculation, we will take into account the number of LMDS cell transmitters that are in the footprint of the 53 dB gain ACTS satellite antenna in the vicinity of the four selected cities. This is done by combining the footprint data of Table VI with the cell area sizes in Table III and the city locations in Figure C. The results are shown below in Table VII.

Table VII. The rainfall zones and LMDS cell sizes for cities at various elevations.

	New York	Seattle	Los Angeles	Miami
Rainfall zone	D2	C	C	E
Elevation Angle (deg)	35.9	31.2	45.8	52.6
NASA assumed cell area (sq. miles)	20	20	20	20
Actual LMDS cell area (sq. miles)	30	82	82	9
NASA error (dB)	-1.8	-6.1	-6.1	+3.5

Thus, as previously discussed, NASA's treatment of all LMDS cell sizes as having the same area results in an error, ranging from -6.1 dB for Seattle and Los Angeles to +3.5 dB for Miami.

D) **Variation of satellite antenna gain over coverage area**: In the case of the 53 dB gain spot beam antenna, the antenna gain does vary considerably over the coverage area. For example, the antenna gain for Seattle is 49.1 dB, for Los Angeles 49.2 dB, for Miami 50.6 dB, and for New York is assumed to be 51.5 dB. This results in an error of more than -3.0 dB at most coverage edges, and on average an error of about -2.9 dB for the four cities chosen, which further improves the actual Io/No margin.

E) **Assumption that all LMDS transmitters have the same polarization**: The same reasoning applies here as was used for the Conus antenna. The NASA calculation error is -3.0 dB for all cases.

F) **Atmospheric losses**: Again, the same reasoning applies here as for the Conus antenna. The error is -0.6 dB for all cases.

Summarizing the results of sections A) through F) for the 53 dB gain ACTS spot antenna for the four particular cities, the total miscalculation factor of NASA is shown in Table VIII below.

Table VIII. Summary of the NASA document calculation errors for the interference into the ACTS 53 dB gain antenna.

	New York	Seattle	Los Angeles	Miami
A) Error/LMDS ant. gain (dB)	-15/-11	-13/-15	-17/-16	-20/-16
B) NASA footprint error (dB)	-7.8	-6.5	-8.4	-9.7
C) NASA LMDS cell area error (dB)	-1.8	-6.1	-6.1	+3.5
D) Variation of ACTS ant. gain (dB)	-1.5 (est)	-3.9	-3.8	-2.4
F) Polarization error (dB)	-3.0	-3.0	-3.0	-3.0
F) Atmospheric losses (dB)	-0.6	-0.6	-0.6	-0.6
Total Error in NASA Calc. (dB)	-29.7/ -30.7	-33.1/ -31.1	-38.9/ -37.9	-34.4/ -30.4
NASA Calculated Interference Io/No (dB)	-1.7	-1.7	-1.7	-1.7
Interference after error correction (dB)	-31.4	-32.8	-39.6	-30.4

Accordingly, the maximum potential interference, given calculations for four widely disparate city locations and conditions and two LMDS antennas, is at least 30.4 dB below the ambient noise (or $1 \div 1096 = .0009$ of noise level at the NASA receiver). Since, by NASA's estimate, the interference would be sufficiently low at only 10 dB below the noise, the LMDS system yields a level of isolation that is at least 20.4 dB better than that suggested by NASA, an improvement factor of more than 110 greater than required.

CONCLUSION

In conclusion, Io/No at the NASA satellite receiver is a minimum -30 dB, even using the NASA assumptions. Thus, LMDS cannot interfere with NASA.

ADDITIONAL POINTS OF CLARIFICATION

There are additional points made in the NASA Document which require clarification. These are listed and discussed below:

1. (Page 17) "The cost of implementing cable heads in each and every cell or, alternatively, of distributing signals from a single source to each cell casts doubt about the economic viability of LMDS."

   However, in the LMDS solution, point-to-point direct (or intermediate repeated for non-line-of-sight) microwave links cross connect all cell nodes. This is accomplished simply by using a directional coupler which samples the master (node A) transmitter. The sampled signals are amplified and passed to a high gain parabolic antenna with 35-40 dB gain at the same polarization as incident to the cell. Adjacent cell receivers amplify and repeat again but change to the orthogonal polarization. There is also an opportunity at these repeaters to add or delete programming material, a unique characteristic of the LMDS system, which allows for customized demographic programming, shopping, local advertising and various forms of interactivity. The repeaters do not significantly detract from the video quality due to the analog FM modulation scheme employed. This form of repeater backbone has been demonstrated in the implementation of LMDS in Brighton Beach, New York.

2. (Page 17) "It would appear that it would be difficult, at best, to find feasible sites for many towers that would be required and that public resistance to siting of these towers could be intense."

First, the LMDS antenna can be as small as 2 square inches to a maximum 4 square feet, hardly intrusive enough to elicit public resistance. The antenna is served by a connecting wave guide of only 0.3" by 0.15" cross section, of whatever length is required. This wave guide can be enclosed within a 1 to 4.5 inch diameter, hollow mounting pipe. The actual transmitter is similar in size to a large suitcase and can be mounted either on the top of the building beneath the antenna or contained in a small closet or enclosure within a building below roof level. Roof space, aside from the World Trade Center, is readily available at very low cost throughout New York and other areas via the "Antenna Site Locater" book, and, for an object as unobtrusive as an LMDS transmitter at very modest cost.

3. (Page 19) "Polarization discrimination would be virtually non existent because the coupling between the LMDS antenna and the earth station antenna would occur through a sidelobe or backlobe of the FSS earth station antenna or the LMDS antenna."

As implied in 2. above, NASA appears to be unfamiliar with basic patch (phased array) antenna design at millimeter waves (Figure C) to be used by LMDS. Note that the vertical to horizontal (V-H) isolation is a minimum of 37 dB throughout 360° and typically as much as 44 dB.

4. (Page 22) "[I]f an LMDS system is implemented that is later found to have insufficient margin..."

The Sarnoff report (page 22, Appendix B of Reference 3) contains a table which reveals that the rain fade causes a carrier-to-noise ratio (C/N) deterioration of 13.4 dB, resulting in a video signal-to-noise ratio (S/N) equal to 42 dB (Grade 3.3), which is 4.4 dB above zero deviation threshold (page 13). Moreover the actual rain fade by CCIR tables (Reference 7, pages 633 and 742) is 13.8 dB. Accordingly, there is a minimum margin of 5.6 dB. This is quite good, considering the fact that intense rainfall is generally limited to small areas. The LMDS margin in fringe areas during clear days is nearly 20 dB!

5. (Page 16) "Fade margins of 30 dB could be required in clear weather and in excess of 30 dB in rain."

This assertion is inaccurate. Since LMDS is cellular, and the transmitter is at the cell center, rain fall attenuation is calculated along the radius only, not the cell diameter. Thus, a 6 mile diameter cell in New York has a radius of only 3 miles, and 3 miles x 4.6 dB/mile (per the CCIR Handbook) = 13.8 dB fade by CCIR calculation and 15.O dB fade by satellite calculations. This is far from 30 dB.

Clear weather fade, due to inhomogeneity of the atmosphere, is calculated by the classic Barnett-Vignant reliability equation (page 97 Reference 8) as:

Fade Margin = 30 log d + 10 log (6ABf) - 10 log (1-R) -70

where

1-R = reliability

A = roughness factor

= 4 for very smooth terrain

= 1 for average terrain

= 1/4 for very rough terrain

B = 1 for worst month

= 1/2 for hot humid areas annual probability

= 1/4 for average areas annual probability

= 1/8 for dry areas annual probability

Typical clear weather fade margin is less than 3 dB.

The important point to keep in mind is that clear weather fade cannot be added to rain fade. By definition, during rainfall the atmosphere is homogenous and atmospheric fade, due to inhomogeneities, is not present. In the LMDS design, to be conservative, the larger of the two fade margins is employed.

References

1. Comments of The National Aeronautics and Space Administration" CC Docket No. 92-297, RM 7372, March 16, 1993.

2. Reply Comments of Suite 12 Group, CC Docket No. 92-297, April 15, 1993, Appendix 4, An Analysis of Uplink LMDS Interference to the NASA ACTS Satellites, April 11, 1993.

3. Suite 12 Group Petition for Rulemaking, September 23, 1991.

4. "Linear Amplifier Combines," Johnson and Myer, AT&T Bell Laboratories, 1987 IEEE.

5. "Investigation of Multiple FM/FDM Carriers Through a Satellite TWT Operating Near to Saturation," Westcott and Eng, IEEE 1967 June.

6. "World Book Encyclopedia."

7. "Reference Manual for Telecommunications Engineering," Roger Freemen, John Wiley & Sons.

8. "Digital Communications," Feher, Prentice Hall.

Figures

Appendix